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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

EOP3026 – OPTOELECTRONICS DEVICES (NE)

25 OCTOBER 2017
2:30 P.M – 4:30 P.M
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of 5 pages with 4 questions only.
2. Answer all questions.
3. Please print all your answers in the Answer Booklet provided.

Question 1 [25 marks]

- (a) (i) Explain why a direct bandgap semiconductor is more efficient for light emitting diode (LED) as compared to an indirect bandgap semiconductor. [3 marks]
- (ii) How can you fabricate an efficient LED from an indirect bandgap semiconductor alloy such as $\text{GaAs}_{1-y}\text{Py}$? Give a value of y for indirect bandgap. [3 marks]
- (b) The output wavelengths of a LED is related to the spread of photon energies $\Delta(h\nu) = 3k_B T$ between the half-intensity points.
- (i) Given that $\lambda = \frac{c}{\nu}$ and the corresponding linewidth is $\Delta\lambda$ between the half intensity points in the output spectrum, obtain $\Delta\lambda = \lambda_o^2 \frac{3k_B T}{hc}$ where λ_o is the peak wavelength. [3 marks]
- (ii) Calculate spectral linewidth of an infrared LED (800 nm) at 300 K that is caused by the thermal effect on photon energy. [3 marks]
- (iii) The LED output spectrum changes with the temperature, sketch three output spectra to explain the effect of its operating temperature. [3x2 marks]
- (c) With aid of simple sketches, briefly describe the mechanism, device structure and spectrum of a white LED by incorporating a suitable phosphor. [7 marks]

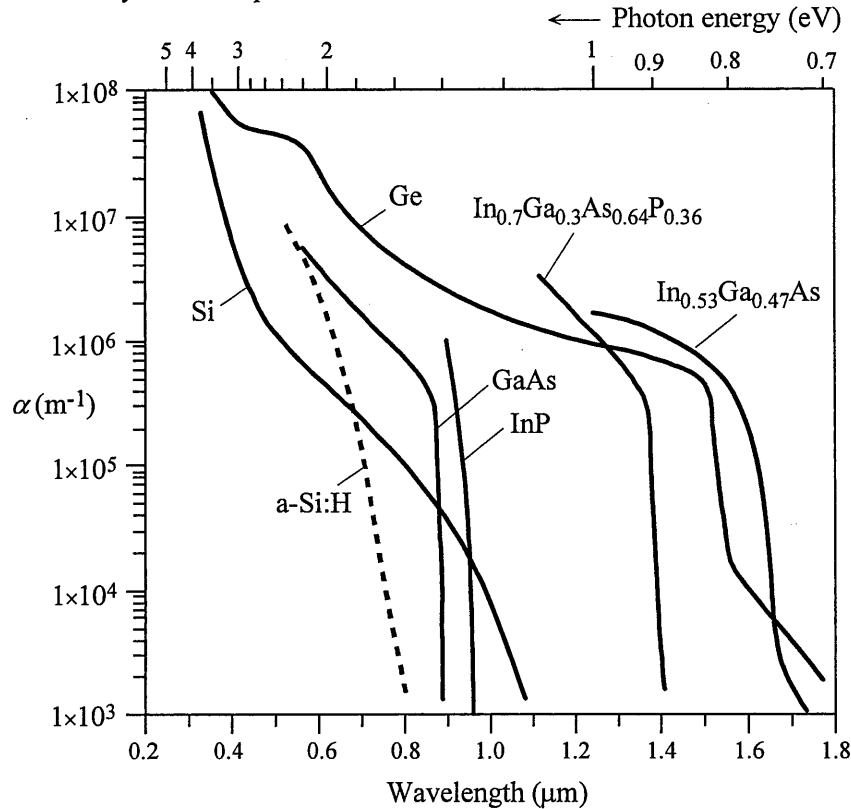
Question 2 [25 marks]

- (a) List four distinct characteristics of laser light. [1 × 4 marks]
- (b) How are LEDs and laser diodes used in optical communication? [2 marks]
- (c) Explain with proper diagram how lasing can be achieved by using semiconductors considering
- (i) Excitation and population inversion
- (ii) Light emission and amplifications [4 + 5 marks]
- (d) What are the differences in the design of a double heterostructure laser and a pn homojunction based semiconductor laser? Describe briefly the advantages of a double heterostructure laser. [1 + 3 marks]
- (e) A laser diode X1 is operating at 1550 nm for use in optical communications. The threshold current is 10 mA. At $I = 30$ mA, the output optical power is 10 mW, and the voltage across the diode is 2.2 V. Calculate external quantum efficiency (QE), external power efficiency (conversion efficiency), and the slope efficiency of the laser diode. [6 marks]

Continued ...

Question 3 [25 marks]

- (a) Figure Q3 shows the absorption coefficient of various semiconductors which are commonly used in optoelectronics.



Absorption coefficient (α) vs. wavelength (λ) for various semiconductors
Figure Q3

- (i) Give two example of semiconductors which have direct bandgap and two semiconductors which have indirect bandgap.
[1 × 4 marks]
- (ii) Give two semiconductors that can be used in optical communication at 1.3 and 1.55 μm .
[1 × 2 marks]
- (iii) Calculate the optical penetration depth if light with the following wavelength is incident onto Si
i. 400 nm
ii. 600 nm
iii. 800 nm
[1 × 3 marks]

Continued ...

- (iv) Draw and label accordingly a diagram of a reversed biased Si p^+n junction photodetector where
 L_e , the diffusion length of electrons in p-side to the depletion region is $0.1 \mu\text{m}$;
 L_h , the diffusion length of holes in the n-side to the depletion region is $10 \mu\text{m}$;
 L_p , the width of the neutral p region is $0.5 \mu\text{m}$;
 W , the width of the depletion region is $1 \mu\text{m}$.
Calculate and mark the useful photogeneration region in the diagram.
[7 marks]
- (v) Which region does light with the wavelengths in (iii) will be absorbed in the Si p^+n junction photodetector in (iv). Discuss the process and responsivity of photodetection for each wavelength.
[6 marks]
- (b) Suggest a design of photodiode where photodetection can be improved. Justify your selection.
[1+2 marks]

Question 4 [25 marks]

- (a) (i) Sketch and label a typical pn junction solar cell. [2 marks]
- (ii) Name three types of silicon-related materials commonly used for solar cell application, and compare their efficiencies.
[3+1 marks]
- (iii) With aid of an equivalent circuit, discuss the effect of series resistance and shunt resistance of a solar cell.
[4+2 marks]
- (b) (i) Define the efficiency of a solar cell. [2 marks]
- (ii) Calculate the maximum output power and efficiency of a solar cell with an open circuit output voltage of 0.4 V and a short circuit current of 70 mA when illuminated directly with light of intensity 1 kW m^{-2} . The fill factor is 0.7 and the solar cell has an area of $1 \text{ cm} \times 1 \text{ cm}$.
[4 marks]
- (iii) Name two factors which usually reduce the efficiency of a Si solar cell.
[2 marks]
- (c) By means of a simple diagram, briefly describe what is a tandem solar cell?
[5 marks]

Continued ...

PHYSICAL CONSTANTS

Speed of light:	$c = 3.0 \times 10^8 \text{ m/s}$
Electronic charge:	$e = 1.6 \times 10^{-19} \text{ C}$
Planck's constant:	$h = 6.63 \times 10^{-34} \text{ Js}$
Permittivity in vacuum:	$\epsilon_o = 8.85 \times 10^{-14} \text{ F/cm}$
Permeability in vacuum:	$\mu_o = 4\pi \times 10^{-7} \text{ H/m}$
Free electron mass:	$m_o = 9.11 \times 10^{-31} \text{ kg}$
Boltzmann's constant:	$k_B = 1.3806 \times 10^{-23} \text{ J/K}$
Thermal voltage:	$V_t = kT/e = 0.0259 \text{ V}$

End of Paper